



National Transportation Safety Board Washington, D.C. 20594

Hazardous Materials Accident Brief

Accident No:	DCA03MZ002
Transportation Mode:	Highway
Location:	Middletown, Ohio
Date of Accident:	August 22, 2003
Time:	8:20 a.m. eastern daylight time
Carrier:	Amerigas Corporation
Shipper:	AK Steel Corporation
Vehicle:	MC-331 cargo tank
Injuries:	5 people treated and released
Property Damage:	About \$25,000
Material Released:	Anhydrous ammonia, a poisonous and corrosive gas
Type of Accident:	Cargo tank head fracture

The Accident

At 7:17 a.m., on August 22, 2003, an Amerigas Corporation (Amerigas) cargo tank semitrailer arrived at the AK Steel Corporation (AK Steel) facility in Middletown, Ohio. The driver pulled the vehicle up to the fill location and helped an AK Steel employee hook up to the fittings for a plant storage tank. According to the driver, about 7:40 a.m., the AK Steel employee began transferring anhydrous ammonia, a poisonous and corrosive gas, from the storage tank to the cargo tank. The driver said that it took about 30 minutes to equalize the pressure between the storage tank and the cargo tank. He said that once the pressure was equalized, the internal pressure in the cargo tank was 130 pounds per square inch gauge (psig).

About 8:20 a.m., while the cargo tank was still being loaded, its front head cracked open, releasing vapor. The driver, who had been resting in the tractor, got out and saw the escaping vapor. He said that he activated the emergency shut off device for the cargo tank and that according to the gauges, the cargo tank was a little less than half full, the internal pressure was about 170 psig, and the temperature of the anhydrous ammonia was 80 degrees F.

About 100 employees and contract workers were evacuated from the buildings downwind of the cargo tank and moved to safer locations. Five people were treated for inhalation injuries and released. The cost of repairing and replacing damaged equipment was about \$25,000.

Cargo Tank Information

The accident cargo tank was a U.S. Department of Transportation (DOT) specification MC 331 cargo tank. Its serial number was 59721, and it had been manufactured by Lubbock Manufacturing Company¹ in 1977. The cargo tank was made of ASTM A517 quenched and tempered steel.² “QT” was stenciled to the right of the cargo tank’s specification plate to show that the tank was made of quenched and tempered steel. (See figure 1.) As manufactured, the nominal thickness of the shell was 0.399 inch, and the minimum thickness of the heads was 0.250 inch. Each of the two heads was a welded assembly of eight pieces of formed steel: a center round portion surrounded by seven separate radial pieces that were welded to the tank shell. (See figure 2.) The water capacity of the tank was 10,600 gallons. It had a maximum allowable working pressure of 265 psig at 150 degrees F.

¹ Lubbock Manufacturing Company, Lubbock, Texas, sold its assets to Evans Products, Inc., in December 1980. Cargo tanks were manufactured under the name Evans Tank Company until 1984, when the company ceased operations.

² Quenching and tempering is a heat treatment intended to improve the characteristics of steel, including increasing the yield strength. Yield strength is the stress at which a material starts to permanently deform.



Figure 1. Accident cargo tank with “QT” by the vehicle specification plate.

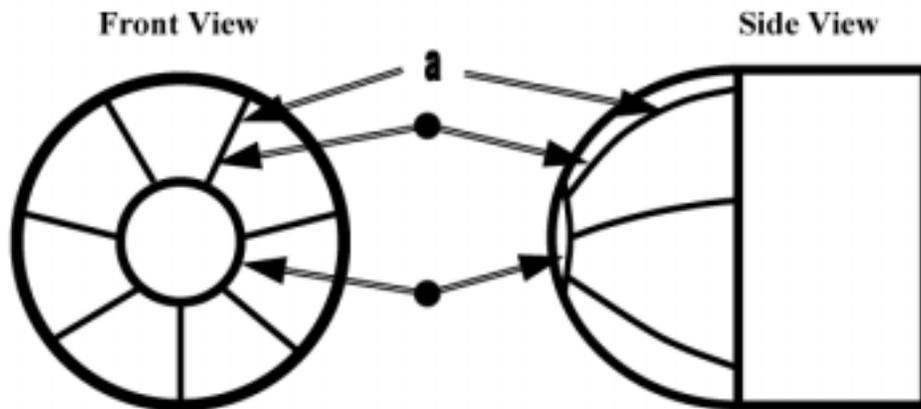


Figure 2. Schematic drawings of front head showing the crack locations (“a” arrow shows the location of the through-wall crack; arrows without labels show the locations of other cracks).

Midwest TankWorks, Inc., had done the last DOT-required tests³ on the cargo tank: a hydrostatic test and a magnetic particle inspection in March 2002 and a visual inspection in March 2003. No exceptions had been noted.

Postaccident Examination

A postaccident examination revealed a 16-inch long through-wall crack next to the radial weld in the front head at the 1 o’clock position. (See figure 3.) An internal inspection and magnetic particle inspection also revealed two additional cracks that did not penetrate through the metal: one closer to the center portion of the head on the same radial weld as the through-wall crack, and the other on the weld between the center portion of the head and the radial piece at the 3-to-4 o’clock position (see figure 2).

³ Title 49 CFR section 180.407 requires MC 331 cargo tanks to be hydrostatically tested every 5 years and visually inspected annually. The section also requires that all MC 331 cargo tanks that are constructed of quenched and tempered steel and used to transport anhydrous ammonia be given a magnetic particle inspection just before and in conjunction with the hydrostatic test.



Figure 3. Through-wall crack in tank head.

The through-wall crack was opened at the Safety Board materials laboratory. Cleaning the opened crack revealed a granular surface that had no indications of crack arrest marks. Scanning electron microscopic (SEM) examinations of typical sections removed from the crack surfaces showed that almost the entire surface topography was composed of corrosion damaged intergranular separation.

The bending forces generated when the through-wall crack was opened also opened a previously undetected crack near one end of the through-wall crack. The undetected crack was about 3 inches long. SEM examinations found the crack topography to be very similar to the surfaces of the through-wall crack, corroded intergranular separation.

Stress-Corrosion Cracking

According to the American Society for Metals' *Metals Handbook, Desk Edition*,⁴ intergranular fracture in carbon steel in the presence of a caustic material, such as anhydrous ammonia, is typical of stress-corrosion cracking. Stress-corrosion cracking occurs in a susceptible material when it is exposed to sustained tensile stresses and a specific environment.

A paper by A. W. Loginow titled *Stress-Corrosion Cracking of Steel in Liquefied Ammonia Service*⁵ said that in the 1950s, the Agricultural Ammonia Institute instructed a research committee to find out why a number of carbon steel tanks containing anhydrous ammonia had failed. The committee determined that the failures were most likely caused by stress-corrosion cracking and that the probability of cracking increased as the yield strength of the steel increased. Testing showed that the addition of at least 0.1 percent water by weight⁶ to the anhydrous ammonia inhibits stress-corrosion cracking in carbon steel. The committee recommended, in part, that ammonia contain at least 0.2 percent water to inhibit cracking.

Mr. Loginow also said that stress-corrosion cracking began to occur in DOT specification cargo tanks in the mid-1960s because improvements in production technology had increased the purity of the ammonia by reducing the water content. During that period, a DOT-initiated examination of cargo tanks constructed from ASTM A517 quenched and tempered steel revealed a strong relationship between anhydrous ammonia that contains less than 0.2 percent water and the increased incidence of stress-corrosion cracking in cargo tanks. As a result, in 1975, the DOT adopted regulations under which cargo tanks made of quenched and tempered steel could be used for anhydrous ammonia only if the solution contained at least 0.2 percent water.

The Hazardous Materials Regulations (Title 49 *Code of Federal Regulations*, Parts 171-180) require that anhydrous ammonia transported by highway be in either DOT specification MC-330 or MC-331 cargo tanks. Section 173.315(a), note 14, provides that such a cargo tank is authorized for all grades of anhydrous ammonia if the tank is not constructed of quenched and tempered steel (NQT). If the cargo tank is constructed of quenched and tempered (QT) steel, as the accident tank was, it is authorized only for anhydrous ammonia having a minimum water content of 0.2 percent. Each cargo tank must be marked near the specification plate with the letters "NQT" or "QT," as applicable.⁷ The shipping papers for anhydrous ammonia transported by highway in a cargo tank must be marked, as applicable, with either "NOT FOR Q and T TANKS" or "0.2 PERCENT WATER."⁸

⁴ Boyer, Howard E. & Gall, Timothy L., *Metals Handbook, Desk Edition*, American Society for Metals, Metals Park, Ohio, 1985, Section 32-24.

⁵ Loginow, A.W., *Stress-Corrosion Cracking of Steel in Liquefied Ammonia Service*, National Board of Boiler and Pressure Vessel Inspector "Bulletin," Volume 45, No. 6, October 1988.

⁶ All percentages of water in anhydrous ammonia that are referred to in this paper are calculated by weight.

⁷ Title 49 CFR section 172.328(c).

⁸ Title 49 CFR section 172.203(h).

Hazardous Materials Information

Anhydrous ammonia is a poisonous and corrosive gas. According to the Center for Disease Control and Prevention's National Institute for Occupational Safety and Health (NIOSH), the low lethal concentration (LC_{LO})⁹ of anhydrous ammonia for humans is 5,000 parts per million (ppm) for a period of 5 minutes. NIOSH also stipulates that the IDLH¹⁰ (immediately dangerous to life or health) of anhydrous ammonia is 300 ppm. Humans can detect the odor of anhydrous ammonia at 3 to 5 ppm.

Under DOT regulations (49 CFR Parts 171-180), anhydrous ammonia is classified and regulated for domestic shipments as a nonflammable gas. Pressure vessels, including cargo tanks, containing anhydrous ammonia must be marked "Inhalation Hazard." Also the shipping papers for those packages must contain the words "Inhalation Hazard" in association with the shipping description.

Anhydrous ammonia is transported as a liquefied compressed gas in pressure vessels (tank cars, cargo tanks, and cylinders). If it is released from the pressure vessel, anhydrous ammonia will immediately return to a gaseous state and expand rapidly.

Anhydrous ammonia is a byproduct of the process of converting coal into coke, which is used as a fuel in blast furnaces to produce steel.

Shipper Information

AK Steel is a steel production facility in Middletown, Ohio. AK Steel produces its own coke and stores the resulting anhydrous ammonia in stationary tanks.

AK Steel sells about six cargo tank loads of anhydrous ammonia a month to Univar USA, Inc., (Univar) in Cincinnati, Ohio. According to AK Steel's records, the accident cargo tank was the only one in which AK Steel's anhydrous ammonia had been transported in the past year.¹¹

AK Steel's laboratory shift manager analyzes each cargo tank load of anhydrous ammonia for moisture. He stated that the anhydrous ammonia almost always contains less than 0.2 percent water. AK Steel's records show that the anhydrous ammonia loaded in the accident cargo tank during the 4 months preceding the accident typically contained less than 0.1 percent water.

⁹ The lowest concentration of a substance that has been reported to have caused death in humans.

¹⁰ NIOSH, in its "Respirator Decision Logic," defines IDLH exposure condition as a condition that poses a threat of exposure to airborne contaminants when that exposure is likely to cause death or immediate or delayed permanent adverse health effects or prevent escape from such an environment.

¹¹ According to the carrier's records, the same cargo tank had also carried loads of anhydrous ammonia from Royster Clark in Finney, Ohio. The shipping papers and records provided by Royster Clark indicate that each load in the cargo tank contained at least 0.2 percent water.

AK Steel generates the shipping papers for the cargo tanks loaded at the Middletown plant. The shipping papers for the 12 months before the accident did not include the words “NOT FOR Q and T TANKS.”

AK Steel’s quality standard operating practice #01-0141-02 for loading trucks and tank cars with anhydrous ammonia in use at the time of the accident did not require loaders to verify before loading that the receiving cargo tank was appropriate for anhydrous ammonia that was less than 0.2 percent water. The practice did not tell the loader what to do if the cargo tank was marked “QT.”

On September 11, 2003, AK Steel revised the quality standard operating practice, which now says:

Before loading check specification plate located on side of tanker, must be labeled NQT. If labeled QT, or has no label, DO NOT LOAD. Contact Shift Manager.

All AK Steel employees involved in loading anhydrous ammonia into cargo tanks are presently being trained in the revised quality standard operating practice.

Additionally, AK Steel’s shipping papers for anhydrous ammonia now contain the words “NOT FOR Q and T TANKS.”

Carrier Information

The cargo tank semitrailer involved in the accident was operated by Propane Transport International (PTI),¹² the Houston-based division of Amerigas.¹³ PTI handles the semitrailer delivery service of liquefied petroleum gas (LPG) to the Amerigas distribution sites. PTI also transports semitrailer loads of LPG and anhydrous ammonia for other customers, such as Univar, which had hired PTI to haul anhydrous ammonia from AK Steel. PTI is the only division of Amerigas that transports anhydrous ammonia. About 1 percent of PTI’s business involves transporting anhydrous ammonia. PTI employs 121 company drivers and 145 owner-operator drivers. (The driver involved in the accident was an owner-operator of his own tractor.) PTI has 331 cargo tanks used to transport LPG (23 of which have also been used to transport anhydrous ammonia) and 7 cargo tanks used exclusively for anhydrous ammonia. The cargo tank involved in the accident was used only for anhydrous ammonia.

PTI uses the safety information about transporting LPG and the hazardous material training examination for drivers that are developed by the Amerigas corporate safety office. PTI has added items to its driver’s training examination that are relevant to operating cargo tank semitrailers. Before the accident, neither Amerigas nor PTI had added questions about anhydrous ammonia to the examination.

¹² PTI was a wholly-owned subsidiary of Amerigas until 1995, when it became an operating division.

¹³ The headquarters of Amerigas are in Valley Forge, Pennsylvania.

PTI safety staff did not check shipping papers regularly to see whether they had the DOT-required information. The PTI manager of safety and accounting said that about 99 percent of PTI's business is LPG and that, except for quantity, the DOT-required information on LPG shipping papers does not vary and does not require close monitoring.

PTI's driver's handbook has information about anhydrous ammonia and the required water content. The 1995 version of the handbook said:

A small amount of water (.002%) [Sic] is added for transportation in transport trailers constructed of T1 steel.^[14]

The same paragraph was still in the handbook in 1998 but no subsequent versions of the handbook were located by PTI until the current handbook. PTI management gave the Safety Board a page from a current driver's manual that was dated September 2003 and said:

A small amount of water (0.2%) is added for transportation in cargo tank trailers constructed of QT (quenched and tempered) steel. This quantity must be marked on the bill of lading. If the anhydrous ammonia contains less than 0.2%, it can only be hauled in a NQT (not quenched and tempered) steel cargo tank.

At meetings between October and December 2003, PTI's regional logistic managers gave drivers copies of the current page about anhydrous ammonia. At the meetings, the managers stressed that drivers should check the shipping papers for the required information before loading anhydrous ammonia. Similar training about anhydrous ammonia will be given by driver trainers as they review the manuals with the new drivers.

The driver of the accident cargo tank took PTI's initial training when he was hired in 1994, and records indicate that in 1995 he received a 1995 driver's handbook; no receipt records for other versions were discovered. After the accident, he said that he had not been told about the requirement that shipping papers for anhydrous ammonia specify the water percentage. He also said that before the accident, he had not known that the anhydrous ammonia carried in his cargo tank should contain a certain amount of water and that it is dangerous to transport anhydrous ammonia that is less than 0.2 percent water in cargo tanks that are made of quenched and tempered steel. On October 21, 2003, he attended the meeting where the regional logistic managers discussed the current page about anhydrous ammonia.

¹⁴ T-1[®] steel is a U.S. Steel Corporation trademark for quenched and tempered steel used in pressure vessels and is comparable to ASTM A517.

Probable Cause

The National Transportation Safety Board determines that the probable cause of this accident was the failure of AK Steel Corporation to establish and implement loading procedures that would prohibit using a cargo tank manufactured of quenched and tempered steel to transport anhydrous ammonia containing less than 0.2 percent water by weight, resulting in stress-corrosion cracking and tank failure. Contributing to the cause of the accident was Amerigas Corporation's failure to tell its drivers that anhydrous ammonia containing less than 0.2 percent water by weight should not be loaded into cargo tanks manufactured of quenched and tempered steel.

Adopted: July 22, 2004